

A CASE STUDY ON CONCRETE PROBLEMS IN UTM

ABDUL AZIZ JULKARNAIN

A project report submitted in partial fulfilment of the
requirement for the award of the degree of
Master of Engineering (Civil – Structure)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

MAY, 2006

This study is especially dedicated to my beloved Mommy and Daddy
Brothers and Sisters,
Beloved *Dear*,
for everlasting love, care, and supports.....

ACKNOWLEDGMENT

With the accomplishment of this project, the author would like to extend the special and greatest gratitude to the project supervisor, Assoc. Prof. Dr. Abdul Rahman Mohd. Sam of Faculty of Civil Engineering, Universiti Teknologi Malaysia for his enthusiastic effort and concern. With his invaluable advice, guidance and encouragement, the author was able to complete this project.

The author gratefully acknowledges the cooperation of En. Mohd. Faizal Wakiman, Pn. Aidalizah, Pn. Meery Zailina, En. Khairuddin Maidin and friends during the data collection.

Deepest thanks to the author's family especially for their encouragement and support in life. Without them the author would not be able to complete the project.

ABSTRACT

This Project was conducted to study the types of concrete problems and its basic category in UTM. The required information was gathered by conducting visual inspection to selected areas and buildings. Interviews with Pejabat Harta Bina and building custodian had made this survey easier when the required information available in their archive. By using fundamental knowledge in relating symptoms of defects to its causes, defects list and weightage of concrete problems based on percentage according to their basic category of cause i.e. Design Deficiency, Material Defect, Construction Error and Maintenance Defect, has been able to be developed and derived. The relationships were determined using approximate approach i.e. deducing initial failure hypotheses (IFH). From this survey, apparently based on the percentage, Design Deficiency has contributed the highest numbers of defective concrete in the survey, followed by Material Defect, Construction Error and Maintenance Defect, by, 34%, 30%, 26% and 10%, respectively. These data are further utilised by relating its causes to durability of the concrete structures in UTM. The results show that, regardless the root of reasons why concrete has become problematic; it has, for sure, given profound impact on the durability of concrete. For instance, crackings induced by design deficiency or by construction error at least permit access and ingress to aggressive agents to propagate deterioration process i.e. corrosion of reinforcement. With these information, it is hoped that the established platform on gathered information about concrete problems in UTM, may able to set forth preliminary reference for any purposes in relating to the above subject. Therefore, preventive measures can be set forth to avoid repetitive concrete problems in UTM in years to come.

ABSTRAK

Projek ini disediakan untuk mengkaji masalah konkrit dan kategorinya di UTM. Untuk mencapai objektif kajian, maklumat yang diperlukan diperolehi melalui kaedah pengamatan dan sesi-sesi temuramah dengan pihak-pihak yang berkaitan yang telah banyak membantu dalam penyiapan laporan projek ini. Dengan menggunakan pengetahuan asas dalam mengenal pasti simptom-simptom kegagalan konkrit dan penyebabnya, senarai masalah konkrit dan peratusan berbanding jumlah kegagalan berdasarkan kategori-kategori am iaitu '*kegagalan rekabentuk*', '*kegagalan bahan*', '*kesilapan pembinaan*' dan '*kelemahan kerja-kerja penyelenggaraan*'; telah dapat ditentukan dengan menggunakan kaedah hipotesis awal kegagalan. Berdasarkan kajian, kategori '*kegagalan rekabentuk*' telah menyumbangkan peratusan yang tertinggi berbanding kategori-kategori lain sebanyak 34% daripada keseluruhan data yang telah direkodkan. Ini diikuti dengan kategori '*kegagalan bahan*', kategori '*kesilapan pembinaan*' dan kategori '*kelemahan kerja-kerja penyelenggaraan*' dengan peratusan masing-masing sebanyak 30%, 26% dan 10%. Data-data ini seterusnya dianalisa dengan mengkaitkannya dengan kebolehtahanlasakan konkrit di UTM. Data yang diperolehi menunjukkan, tanpa mengira kategori penyebab masalah, ia sudah pasti akan mempengaruhi kebolehtahanlasakan konkrit. Contohnya, keretakan yang disebabkan kegagalan pada rekabentuk dan teknik pembinaan yang salah akan memberikan ruang untuk agen-agen agresif menyebabkan proses kemerosotan kualiti konkrit terutamanya pengaratan pada tetulang konkrit. Dengan maklumat-maklumat ini, diharapkan ia dapat menyediakan satu platform pengumpulan masalah-masalah konkrit di UTM dan juga sebagai rujukan awal untuk tujuan berkaitan masalah tersebut. Oleh itu, langkah-langkah pencegahan dapat ditentukan supaya masalah-masalah konkrit di UTM tidak akan berulang di masa akan datang.

TABLE OF CONTENTS

CHAPTER	DESCRIPTION	PAGE
	TITLE	i
	STUDENT'S DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xi
	LIST OF FIGURES	xii
	LIST OF APPENDICES	xvii
 1	 INTRODUCTION	
	1.1 Introduction	1
	1.2 Research Background	2
	1.3 Research Objectives	5
	1.4 Scopes of Research	5
 2	 LITERATURE REVIEW	
	2.1 Introduction	7
	2.2 Durability	8
	2.2.1 Environmental and Usage Factors	10

2.2.1.1	Abrasion and Erosion	10
2.2.1.2	Climatic Condition	11
2.2.1.3	Atmospheric Pollution	11
2.2.1.4	Biological Attack	11
2.2.1.5	Chemical Attack	11
2.2.2	Compositional and Production Factors	12
2.2.2.1	Types of Cement and Cement Content	13
2.2.2.2	Types of Aggregate	15
2.2.2.3	Degree of Compaction and Air Content	16
2.2.2.4	Water/Cement Ratio (w/c) and Curing	17
2.3	Quality Control	19
2.4	Distinguishing Durability Problem and Design Problem	20
2.4.1	Determining Structural Integrity	21
2.4.2	Pre-Determining of Structural Integrity	23
2.4.2.1	Inadequate Structural Design	23
2.4.2.2	Poor Design Details	24
2.4.3	Types of Concrete Cracks, Causes of Cracks, Remedial Works and Time of Appearance	25
2.5	Non-Destructive Tests	27
2.5.1	Covermeter	28
2.5.1.1	Reliability, Limitations and Applications	29
2.5.2	Rebound Hammer Method	30
2.5.3	Ultrasonic Pulse Velocity Test (UPV)	31
3	METHODOLOGY	
3.1	Introduction	34
3.2	Methods in Gathering Raw Data	35
3.2.1	Site Visits	35
3.2.2	Interviews	38
3.3	Methods in Interpreting and Analysis of Raw Data	39
4	RESULTS AND FINDINGS	
4.1	Introduction	43

4.2	Common Defects and Their Causes	44
4.2.1	List of Defects Through Findings	45
5	ANALYSIS OF RESULTS	
5.1	Introduction	55
5.2	Design Deficiencies	55
5.2.1	Predictable Design Deficiencies	56
5.2.2	Unpredictable Design Deficiencies	63
5.3	Material Defects	72
5.4	Construction Errors	82
5.5	Maintenance Defects	93
6	DISCUSSION OF FINDINGS	
6.1	Introduction	98
6.2	Concrete Problems vs. Durability of Concrete	98
6.3	Design Deficiencies	101
6.4	Material Defects	103
6.5	Construction Errors	104
6.5.1	Adding Water to Concrete	105
6.5.2	Improper Alignment of Formwork	105
6.5.3	Improper Consolidation	105
6.5.4	Improper Curing	106
6.5.5	Improper Location of Reinforcing Steel	106
6.5.6	Movement of Formwork	107
6.5.7	Premature Removal of Shores or Reshores	107
6.5.8	Settling of the Concrete	107
6.5.9	Settling of the Subgrade	107
6.5.10	Vibration of Freshly Placed Concrete	108
6.5.11	Improper Finishing of Flatwork	108
6.6	Maintenance Defects	109
6.6.1	Prevention of Differential Settlement or Slope Subsidence	110
6.6.2	Prevention of Staining on Concrete Surface	110

6.6.3	Building Maintenance Manual/Log Book	112
6.7	Corrosion of Reinforcement	113
6.7.1	Protection of Steel in Concrete	117
6.7.2	Mechanism of Corrosion and Corrosion Protection	117
6.7.3	Carbonation of Concrete	118
6.7.4	Chloride Attack	119
6.7.5	Corrosion of Reinforcement	120
6.7.6	Preventive Measures	122
7	CONCLUSIONS AND RECOMMENDATIONS	
7.1	Introduction	124
7.2	Summary of the Findings	124
7.3	Conclusions	125
7.4	Recommendation for Future Study	126
	REFERENCES	128
	APPENDICES	130

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Table adapted from Table 6.1 from BS8110: Part 1.	13
2.2	Typical composition of Ordinary Portland Cement.	15
2.3	Classification of intrinsic cracks.	26
3.1	Visual examination of concrete problems: items for checklist.	36
4.1	List of defects identified through survey.	45
4.2	Data used to develop chart in Figure 4.1.	52
4.3	Data for Academic Buildings aged more than 10 years.	53
4.4	Data for Academic Buildings aged less than 10 years.	53
4.5	Data for Residential Buildings aged more than 10 years.	53
4.6	Data for Residential Buildings aged less than 10 years.	54
6.1	Vibration limits for freshly placed concrete.	108
6.2	Conditions and features of reinforcement corrosion.	115
6.3	The manifestation of reinforcement corrosion.	117

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Figure depicts concrete have been severely eroded and start spalling.	3
1.2	Figure depicts pathways slab transversely cracking.	4
1.3	Figure depicts apron slab start cracking and surface is abraded.	4
2.1	Biological Attack on concrete.	12
2.2	Water / cement ratio 0.3.	17
2.3	Water / cement ratio 0.5.	17
2.4	Water / cement ratio 0.8.	18
2.5	Some typical crack types: (a) reinforcement corrosion; (b) plastic shrinkage; (c) sulphate attack; (d) alkali/aggregate reaction.	21
2.6	NDT was carried out to check the structural integrity of the beam by getting essential parameters such as cover thickness, numbers of reinforcement, size of reinforcement, location of reinforcement and stirrups.	22
2.7	NDT was carried out to check the structural integrity of the beam by getting essential parameters such as cover thickness, numbers of reinforcement, size of reinforcement, location of reinforcement and stirrups.	23
2.8	Schematic representation of the various types of cracking which can occur in concrete (see Table 2.3).	25
2.9	Typical simple covermeter .	28
2.10	Typical simple covermeter circuitry.	29

2.11	Most common used rebound hammer, Schmidt Hammer.	30
2.12	The Schmidt Hammer in use.	31
2.13	Commonly used UPV, 'PUNDIT'.	32
2.14	Placement of pundit test equipment.	33
3.1	Pejabat Harta Bina.	38
3.2	Reinforcement corrosion is related to the pattern of distress (longitudinal cracking) along prop for Monsoon Drain.	41
3.3	Illustration of Methodology.	42
4.1	Percentage of Defects based on main category and age.	51
5.1	Combination of shear and flexural cracks clearly shown.	57
5.2	Longitudinal also detected on the soffit of the beam. (enlarged view).	58
5.3	Combination of shear and longitudinal cracks.	58
5.4	Typical pattern of cracks on slab in residential buildings.	59
5.5	Staining on wall due to leakage.	60
5.6	Staining on wall due to leakage.	60
5.7	Watermarks at intersection joints of columns and beams.	61
5.8	Watermarks at intersection joints of columns and beams. Seems stalactite (Calcium salts) has been formed.	61
5.9	Typical arrangement of reinforcing bars at intersection.	62
5.10	The building seems slipping on one side based on the cracks appeared.	63
5.11	Pusat Komposit (Block P23).	64
5.12	Cracks appeared on beam.	65
5.13	Diagonal distortion cracking caused by differential foundation settlement due to hard/soft contact pressure.	66
5.14	Differential settlement of external stack wall resulting	66

	from basement extending over part plan area only.	
5.15	Settlement of internal wall due to soft spot caused by migrating swallow hole.	67
5.16	Front view of Pusat Komposit.	68
5.17	Cracks on beam (zoomed-in view).	69
5.18	Cracks on column (enlarged view).	69
5.19	Retaining wall near Pusat Komposit (Block P23).	70
5.20	Slope at Block M47.	70
5.21	Cracks on wall, Block M47.	71
5.22	Cracks on apron slab, Block M47.	71
5.23	Cracks on drain wall, Block M47.	72
5.24	Monsoon drain at Kolej 16.	74
5.25	Algae resided in the prop and longitudinal cracks are visible.	74
5.26	Stain (rust-colored) implied corrosion of reinforcement had occurred.	75
5.27	Longitudinal stain at the bottom of beam.	76
5.28	Cracks on the perimeter beam.	76
5.29	Retaining wall adjacent to Pusat Komposit.	77
5.30	White deposits show formation of efflorescence / ettringite.	78
5.31	Cavitated concrete surface.	79
5.32	Arrangement of roofing allows rainwater to drop on the surface of slab.	80
5.33	Kitchen rear area at Block L50.	81
5.34	Disintegrated cement paste and aggregate of concrete slab at kitchen area of Block L50.	81
5.35	Transverse cracks on the drain cover adjacent to Masjid Sultan Ismail, UTM.	83
5.36	Crazing cracks and stains (dark green-colored) on concrete floor slab at Block C10 level 1.	84
5.37	Honeycombed concrete at basement level of Block M47.	85

5.38	Exposed reinforcing steel at basement level of Block M47.	85
5.39	Rehabilitated honeycombed concrete but wasn't done properly at basement level of Block M47.	86
5.40	Honeycombed concrete on soffit slab at basement level of Block M47.	87
5.41	Honeycombed concrete on soffit slab at basement level of Block M47 (enlarged view).	87
5.42	Differential settlement at Block M47 adjacent to TNB sub-station.	88
5.43	Differential settlement at rear elevation of Block M47.	89
5.44	Differential settlement on pathway slab at Kolej 16.	89
5.45	Differential settlement at Block L50.	90
5.46	Differential settlement at Block L50.	90
5.47	Rising Dampness on wall.	92
5.48	Rising Dampness on wall at Block S46.	92
5.49	Rising Dampness on wall at Block L50.	93
5.50	Water falls on railing due to leakage at beam junction.	94
5.51	Staining on railing due to leaking water drops.	95
5.52	Joint failure on upper level of beam junction as shown in Figure 5.50.	95
5.53	Roof joint/sealant failure.	96
5.54	Level 1 Block B08 – Linkway.	96
5.55	Plants well grown in between cracks.	97
6.1	Illustration of cracking mechanism due to overstress in structural element.	102
6.2	The three-stage model of corrosion damage.	114
6.3	Progress of carbonation with time of exposure under different conditions: (A) 20°C and 65% RH; (B) outdoors, protected by roof; (C) horizontal surface outdoors in Germany. The values are averages for concrete with w/c ratios of 0.45, 0.60, and 0.80, wet-cured for 7 days.	119

6.4	Spalling of delamination occurs when expansion of reinforcing steel due to corrosion begins.	120
6.5	Graph shows relationship between corrosion rate and pH of concrete.	121
6.6	Illustration of mechanism of corrosion of reinforcement.	122

APPENDICES

APPENDICES	TITLE	PAGE
A	List of Defective Locations in Kolej Perdana	130
B	List of Defective Locations in Kolej Tun Razak	135

CHAPTER 1

INTRODUCTION

1.1 Introduction

With the advancement of concrete technology, concrete are formed in many ways and in enhanced quality. For instance, precast structures have become prominent in the contemporary construction industry, concrete are pre-prepared in the factory before placing it to the construction site area. Furthermore, nowadays, we can see so many ready mixed concrete suppliers, offering various type of concrete. It has become pleasant and a great helpful system especially when dealing with fast-track projects. Hence, with rapid growth of its use for structures skeleton or for aesthetic purpose, nobody can help from being surrounded by material named concrete; housing, bridges, dams, roads, offices and even pathways also made from concrete. Some says, it is like living in a concrete jungle era or concrete-age.

However, inevitably, numbers of records have shown that concrete has been experiencing problems in deterioration, cracks, spalling, corrosion and many more to quote here [1, 2, 3, 4]. These problems has become unfavourable and invited unpleasant feeling to the occupants. Seeing this, most of us take some form of acceptance when seeing problems in concrete. Wide variety of concrete problems may result in many bewildering impressions. Are they due to poor workmanship, were non-compliance materials used, construction errors or perhaps design errors? In fact, there are a lot more of reasons why concrete becomes problematic. Therefore, decisions to overcome concrete problems can be started using heuristics to deal with bounded rationality of such why the problem occurred in the first place. Systematic

errors can result in from use of an incorrect heuristic and the errors, for sure, will appear over and over since the rule used to make decision is flawed from the onset.

Henceforth, engineers may have to learn and understand the behaviour of the concrete problems before implying any repairing methods and learn from the successful implemented solutions done by others before this. Otherwise, time, money and efforts, will be wasted for using wrong implication and heuristic. Therefore, a research should be conducted to get the right implication and heuristic. Nobody should imply solution if there is lacking of complete information on the intended-for-research concrete. Hence, investigations may have to be carried out on certain parameters such as the proportion of the mix, criteria applied to calculate concrete mix, types of supervision during construction; were the materials inspected before use, were the concrete poured complying with the design mix, and many more approaches to get the right implication and heuristic.

Using the above philosophy, a research on concrete problems in UTM ought to be conducted in obtaining the right repairing methods or at least as a general reference tool before doing any construction works.

However, the research in this paper is not about repairing methods but merely a case study research on concrete problems related to durability; investigate and identify concrete problems including locations where they might be, and classify its symptoms to probable causes where in here appropriate preventive measures and repairing methods can be suggested. Still, it is not about repairing methods.

1.2 Research Background

As mentioned previously, concrete problems are so common and yet, there are numerous types of concrete problems that can be inserted in the list if any.

Noticeably, there are many types of concrete problems in UTM such as cracks, deteriorated and abraded concrete; probably due to chemical attack,

construction errors, design errors etc. This has brought the interest to conduct a research on type of concrete problems in the vicinity of Universiti Teknologi Malaysia, Skudai (UTM).

Having this in mind, it is a need that a research on concrete problems in UTM may have to proceed with limitation on its durability aspect due to the fact that concrete problems is an extremely complex subject. It differs from one to another due to different site attributes. Few examples of concrete problems in UTM are shown in Figure 1.1, Figure 1.2 and Figure 1.3:-



Figure 1.1: Figure depicts concrete have been severely eroded and start spalling.



Figure 1.2: Figure depicts pathways slab transversely cracking.



Figure 1.3: Figure depicts apron slab start cracking and surface is abraded.

1.3 Research Objectives

The objectives of the research can be short listed as follows:

- (i) To conduct a study on concrete problems occurring in UTM.
- (ii) To classify the concrete problems and its causes using *initial failure hypothesis* (IFH) method [5].
- (iii) To relate the concrete problems in UTM to the durability aspect of concrete.

1.4 Scopes of Research

The scope of research shall be in line with the concrete problems in durability aspect. Its huge built area encompasses faculties' buildings, residential buildings, library, and facilities buildings such as sports complex, food courts, mosque, banks, student affairs buildings, and administration centre. These buildings and its surroundings shall be the areas where all the data will be sourced out.

During the process of gathering raw data, all types of problems will be recorded and illustrated. Screening and scrutinizing will be carried out to classify the problems prior getting into the main study that is durability problem of concrete, which will be discussed in the Chapter 4, where it presents a logical method for relating the symptoms or observations to the various causes.

In addition, the study is also intended to establish diagnoses on concrete problems in initial failure hypothesis form. The cause or causes for the deterioration of concrete, such as crack problems will be diagnosed and related to common problems that can occur anywhere, anytime in the field of construction site due to the lack of precautions or steps taken to ensure that the concrete was satisfactorily complied in accordance with the requirements of relevant standard.

Finally, all the interpreted and analyzed data will be tabulated in a table form, showing type of problems, weightage by numbers and percentage, and locations

where problems occurred. These data can be used to relate its symptoms to causes of the problem where it may suggest solutions and preventive measures to avoid repetitive problems in the future. In addition, it is hoped that the information from this study can be useful as a preliminary reference to construction players prior executing any construction works or repairing works in the future prospect of the Malaysian construction industry.

REFERENCES

- [1] Kaminetzky D. *Design and Construction Failures: Lessons from Forensic Investigations*. New York. McGraw-Hill, Inc. 1991.
- [2] Feld J. *Lessons from Failures*. Michigan. American Concrete Institute: Monograph No.1. 1967.
- [3] Raikar R.N. *Learning from Failures: Deficiencies in Design, Construction and Service*. New Bombay. R&D Centre. 1987.
- [4] Dhir R.K. *Protection of Concrete*. Cambridge: University Press. 1990.
- [5] Rahman A.A. *Lecture Notes on Forensic Engineering*. Jabatan Struktur dan Bahan, Fakulti Kejuruteraan Awam, Universiti Teknologi Malaysia, Skudai. 2006.
- [6] Perkins P.H. *Concrete Structures: Repair, Waterproofing and Protection*. London. Applied Science Publishers Ltd. 1976.
- [7] Ismail M. *Lecture Notes on Durability of Concrete*. Jabatan Struktur dan Bahan, Fakulti Kejuruteraan Awam, Universiti Teknologi Malaysia, Skudai. 2005.
- [8] Woods H, *Durability of Concrete Construction*. Detroit, Michigan: ACI/IOWA State. 1968.
- [9] Neville A.M. *Properties of Concrete*. 4th Edition. Harlow Essex. England: Longman. 1995.
- [10] U.S. Department of the Interior Water and Power Resources Service. *Concrete Manual*. 8th Edition. USA. John Wiley & Sons. 1981.
- [11] Tattersall G.H. *Workability and Quality Control of Concrete*. Cornwall, Great Britain. Chapman & Hall. 1991.
- [12] British Standards Institution. *Structural Use of Concrete*. London, BS 8110. 1985.
- [13] Mindess S., Young J.F. and Darwin D. *Concrete*. 2nd Edition. Upper Saddle River. N.J.: Prentice-Hall. 2003.

- [14] Blackledge G.F. *Concrete Practice*. U.K.: Cement and Concrete Association (CECA).
- [15] ASTM. *Significance of Tests and Properties of Concrete and Concrete-Making Materials*. Baltimore. ASTM. 1966.
- [16] J.H.B, S.G.M. *Testing of Concrete in Structures*. 3rd Edition. Bishopbriggs, Glasgow: Chapman & Hall. 1996.
- [17] Interview – En. Mohd. Faizal Wakiman, Technical Assistant of Construction Department of Pejabat Harta Bina, Universiti Teknologi Malaysia, Skudai. 2006.
- [18] Interview – Pn. Meery Zailina Hj. Ismail. Penolong Pengurus Asrama Kolej Tun Razak, Universiti Teknologi Malaysia, Skudai. 2006.
- [19] Interview - En. Khairuddin Maidin, Managing Director of KME Enterprise. 2006.
- [20] Parkinson G., Shaw G., Beck J.K. & Knowles D. *Appraisal & Repair of Masonry*. Wiltshire, Great Britain. Thomas Telford Ltd. 1996.
- [21] Baker T. *Making and Placing Concrete*. New York. Longman Group. 1985.
- [22] Chew M.Y.L., Wong C.W. and Kang L.H. *Building Facades: A Guide to Common Defects in Tropical Climates*. Singapore. World Scientific. 1998.
- [23] Chapter 3: Causes of Distress and Deterioration of Concrete, EM 1110-2-2002, 30 June 1995. Web site (<http://www.icri.org>). Accessed, July, 2005.
- [24] Chapter 1: Deterioration of Concrete. Web site (<http://www.icri.org>). Accessed, July 2005.
- [25] Emmons P.H. *Concrete Repair and Maintenance Illustrated*. Kingston. R.S. Means Company, Inc. 1993.